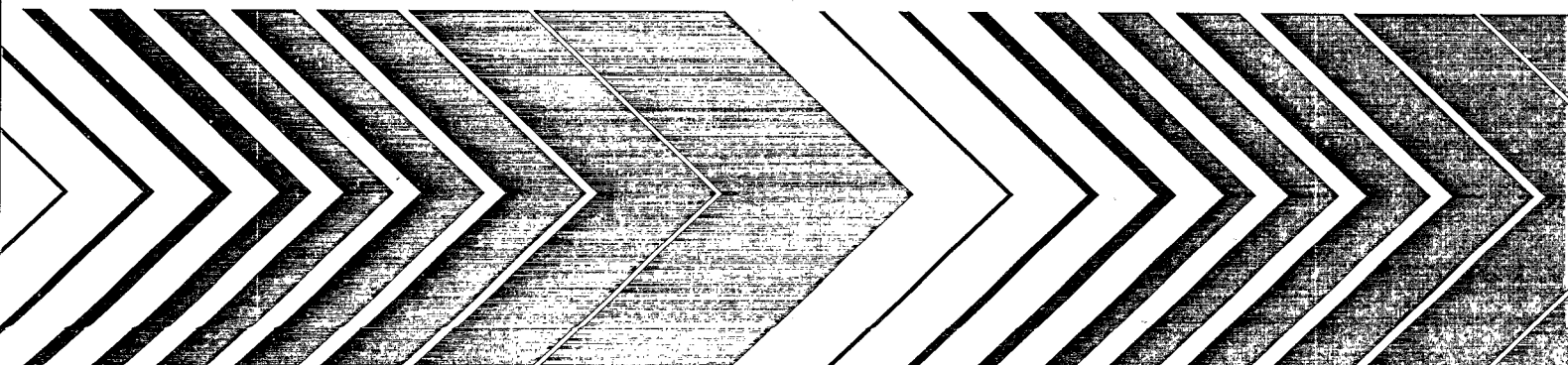
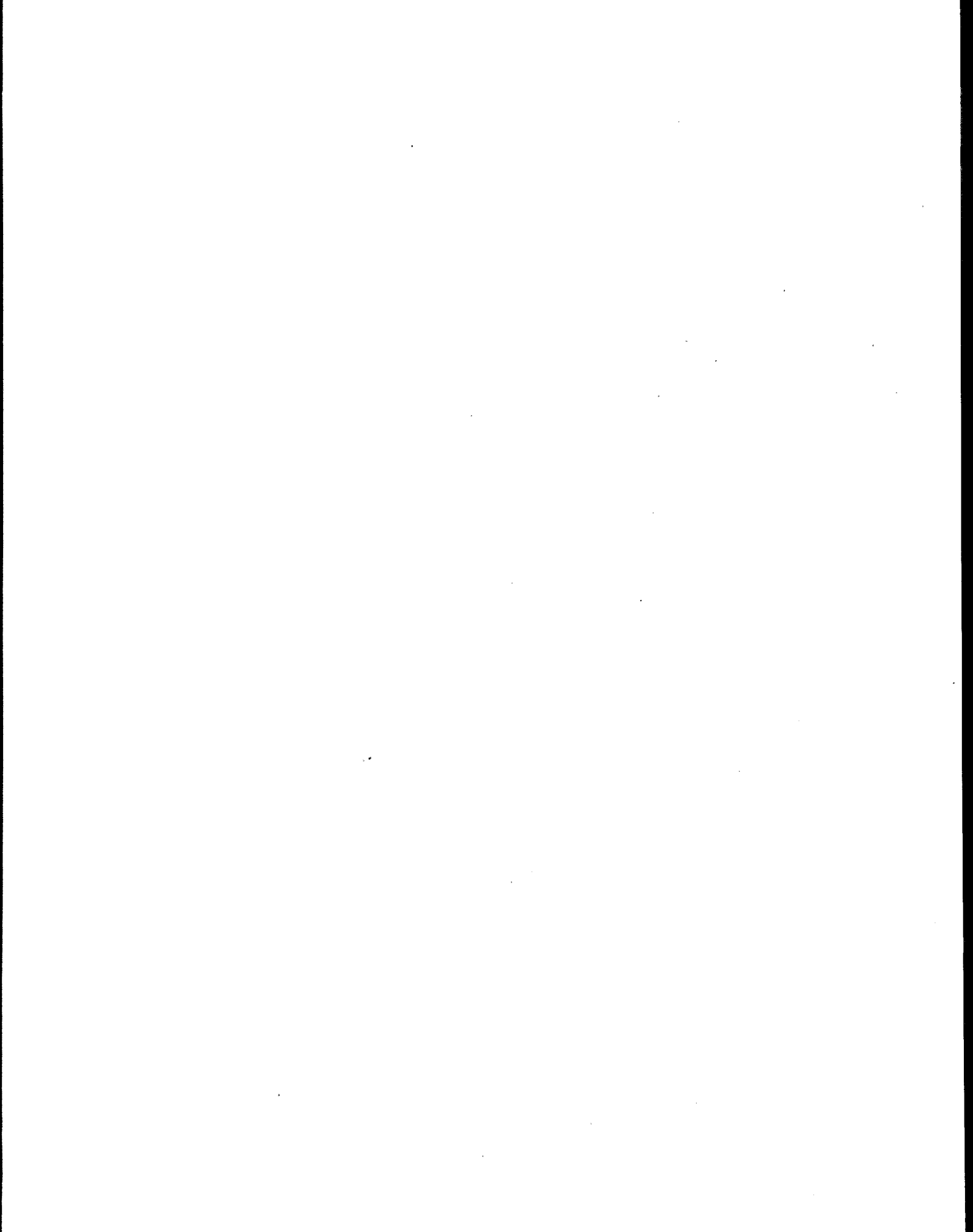




Environmental Profile for Propylene Carbonate





ENVIRONMENTAL PROFILE FOR PROPYLENE CARBONATE

By

Research Triangle Institute
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and

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NATIONAL RISK MANAGEMENT RESEARCH LABORATORY
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Foreword

The U. S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to the air, land, water and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and groundwater; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication is a product of the Laboratory's Life Cycle Engineering and Design research program, an effort to develop life cycle assessment and evaluation tools that can be applied for improved decision-making by individuals in both the public and private sectors. Life Cycle Assessment is a part of the Laboratory's strategic long-term research plan. This document is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

Abstract

This project is sponsored by the U.S. Department of Defense's (DoD's) Strategic Environmental Research and Development Program (SERDP) and led by the U.S. Environmental Protection Agency's (EPA's) Life Cycle Assessment (LCA) Research Team at the National Risk Management Research Laboratory (NRMRL). The research effort described in this report was conducted to support the Life Cycle Engineering and Design (LCED) Program, a cooperative program of both DoD and EPA. Among the objectives of the LCED is demonstrating the effectiveness of analytical tools and environmental techniques to reduce impacts to the environment and costs of operation while maintaining performance standards. The lessons learned from LCED projects will be incorporated into a design guide for DoD process engineers and designers. Environmental information on propylene carbonate (PC) is required for the development of the design guide. This report presents information related to the potential environmental implications of PC.

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Acronyms

BOD	Biochemical oxygen demand
CAA	Clean Air Act
CARC	Chemical agent-resistant coating
CAS	Chemical Abstracts Service
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COD	Chemical oxygen demand
DoD	U.S. Department of Defense
EPCRA	Emergency Planning and Community Right-to-Know Act
GI	Gastrointestinal tract
LCA	Life cycle assessment
LCED	Life Cycle Engineering and Design Program
MEK	Methyl ethyl ketone
MSDS	Material safety data sheet
NMP	N-methylpyrrolidone
NFPA	National Fire Protection Association
PC	Propylene carbonate
ppm	Parts per million
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
SERDP	Strategic Environmental Research and Development Program
TLV	Threshold limit value
EPA	U.S. Environmental Protection Agency
TOC	Total organic carbon
VOC	Volatile organic compound
°C	Degrees Celsius
°F	Degrees Fahrenheit

1.0 Introduction

The research effort described in this report was conducted under cooperating programs of both the Department of Defense (DoD) and the Environmental Protection Agency (EPA). Among the shared objectives of the cooperators is demonstrating the effectiveness of analytical tools and environmental techniques to reduce environmental impacts and costs of operation while maintaining performance standards. This project was sponsored by DoD's Strategic Environmental Research and Development Program (SERDP) and conducted by EPA's Life Cycle Assessment Research Team at the National Risk Management Research Laboratory (NRMRL).

STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM



SERDP was established 2 years ago in order to sponsor cooperative research, development, and demonstration activities for environmental risk reduction. Funded with DoD resources, SERDP is an interagency initiative between DoD, the Department of Energy (DOE), and EPA. SERDP seeks to develop environmental solutions that improve mission readiness for federal activities. In

addition, it is expected that many techniques that are developed will have applications across the public and private sectors.

LIFE CYCLE ASSESSMENT RESEARCH PROGRAM

Since 1990, the NRMRL has been at the forefront in the development of life cycle assessment (LCA) as a methodology for environmental assessment. In 1994, NRMRL established an LCA Team to organize individual efforts into a comprehensive research program. The LCA Team coordinates work in both the public and private sectors with cooperators ranging from members of industry and academia to federal facility operators and commands. The team has published project reports and guidance manuals, including *Life Cycle Assessment: Inventory Guidelines and Principles* and *Life Cycle Design Guidance Manual*. The work described in this report is a part of an expanding program of research in LCA taking place under the direction of NRMRL in Cincinnati, OH.

The research effort described in this report was conducted under the Life Cycle Engineering and Design (LCED) program, a cooperative program of both the DoD and EPA. Among the objectives of the LCED program is demonstrating the effectiveness of analytical tools and environmental techniques to reduce impacts to the environment and costs of operation while maintaining performance standards. To do this, LCED has sponsored three LCA and life cycle-based projects at DoD installations:

- Propylene Carbonate (PC) Blend 2, a depainting alternative to methyl ethyl ketone (MEK)
- Chemical agent-resistant coating (CARC)
- GBU-24 energetics model.

This project is sponsored by DoD's SERDP and by EPA's LCA Research Team at the NRMRL.

1.1 Goals and Scope of this Research

The overall goal of this research is to document the environmental impacts of PC to assist DoD in assessing the life cycle environmental implications of PC and PC-based formulations as viable alternative materials, products, and techniques to paint, depaint, and corrosion control DoD aircraft, vehicles, and equipment in common applications at federal facilities.

A life cycle study encompasses the cradle-to-grave stages of a product, process, or activity, from the acquisition of raw materials to the final disposition. Consistent with life cycle concepts, the study boundaries for the use of PC in painting and depainting operations include the following elements:

- Raw materials acquisition
- Production of intermediate chemicals and materials
- Production of PC
- Use of PC
- Storage and disposal of residual PC.

1.2 Research Approach

Identifying the life cycle environmental implications of PC in DoD painting and depainting operations requires not only a comprehensive search for the use of PC in those operations but also a search for information related to the production, use (in other applications), and disposal of PC.

To develop an environmental profile for PC, the following tasks were conducted and documented:

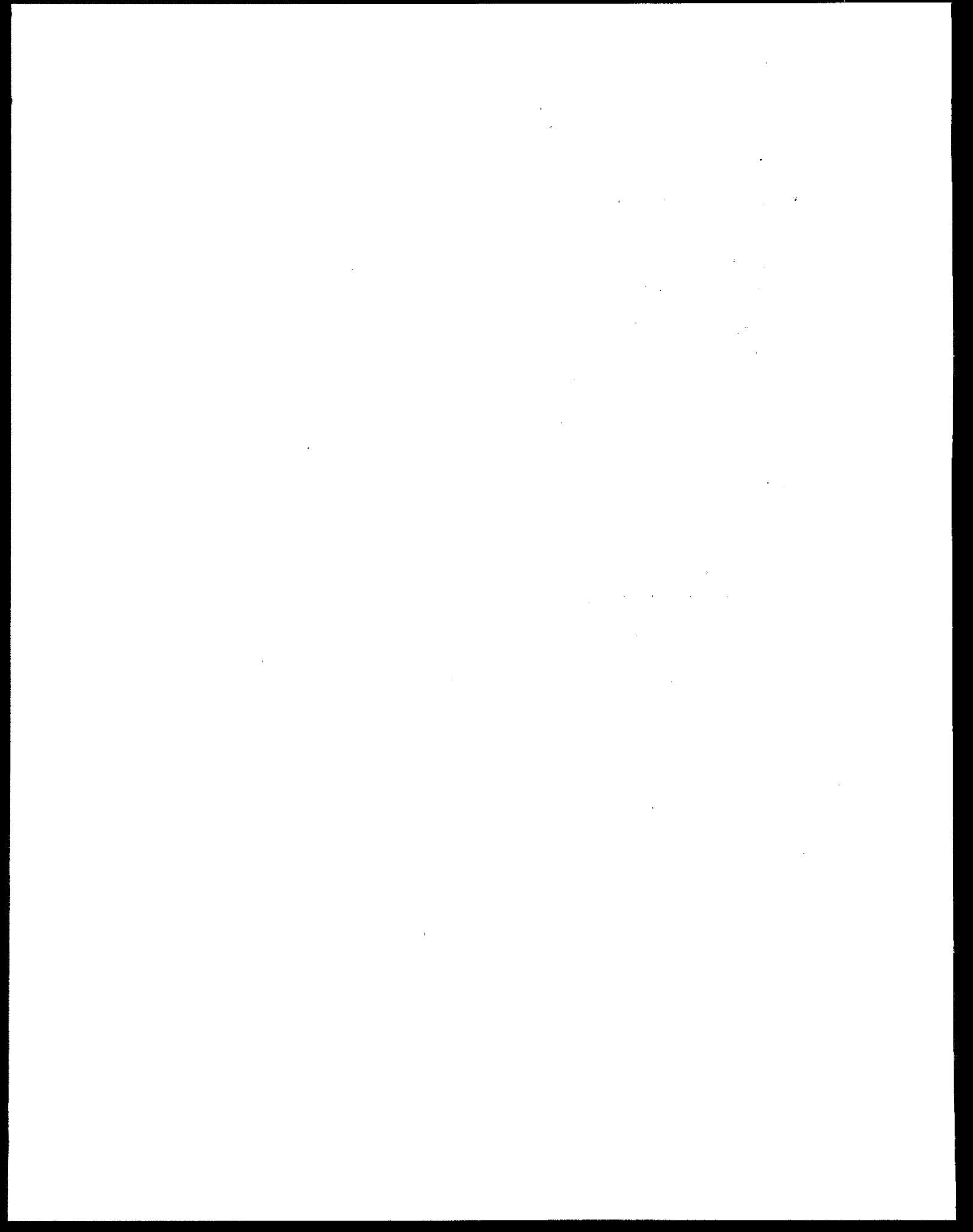
- Conducted a literature search of PC for all environmental impact information and data that can be reasonably acquired
- Collected analyses of the environmental impacts of PC as used in painting and depainting operations
- Contacted responsible individuals in the aerospace industry who have evaluated PC and PC substitutes, as well as those currently using PC
- Provided detailed information on the known ecological and human health impacts of PC, including occupational health and safety implications of the use of PC in aerospace cleaning and depainting operations
- Collected relevant case histories on the use of PC for cleaning and depainting operations.

1.3 Report Organization

This report is organized according to the following sections:

- 2.0 Production and Use of PC
- 3.0 Impact Categories
- 4.0 Data Review
- 5.0 Impact Assessment
- 6.0 Environmental Regulations
- 7.0 Summary
- 8.0 References.

Section 2.0 provides background information on PC and presents several case studies focusing on its use in depainting operations. Key human health and environmental impact categories are identified in Section 3.0. Section 4.0 discusses sources of information, physical and chemical properties, environmental fate and transport, and the toxicology of PC. Section 5.0 identifies the populations at risk of exposure and summarizes the available data on potential impacts to natural resources and ecosystems. Current environmental regulations are reviewed in Section 6.0, and a summary is provided in Section 7.0.



2.0 Production and Use of PC

Propylene carbonate is an organic solvent produced by reacting propylene oxide with carbon dioxide in the presence of a homogeneous catalyst. The process used to manufacture PC is summarized in Section 2.0 of this report. The relatively low vapor pressure, stability, and high flash point of PC, along with its solvency characteristics compared to other solvents, make it suitable for use as a solvent for paints and varnishes, plastics, and epoxides. PC also is used in the following applications:

- Production of fibers and textiles -- as solvent and softener, specifically in extrusion and polymerization into fibers of acrylonitrile and polyamide
- Synthetic and natural fabrics finishing (e.g., improving lightfastness, dirt-proofness, and mechanical and wrinkle resistance)
- Dyeing -- improving the dyeability of fibers
- Removal of carbonyl sulfide (COS) and hydrogen sulfide (H₂S) and small amounts of water from natural and synthesized CO₂-rich gas (e.g., ammonia synthesized gas)
- Extraction of aromatic hydrocarbons from petroleum fractions and from mixtures with aliphatic hydrocarbons
- Extraction of metals from acid solutions (e.g., Bi, Cd, Co, Cu, Au, Fe, Pb, Hg, Mo, Pd, Rh, V, W, and Zn)
- Gel promoter in bentonite-based lubricants
- Organic solvent in electrolytes for high-energy density batteries and electrolytic capacitors
- Personal care agents and cosmetics
- Removal of phenols and alcohols from aqueous solutions
- Component of cooling agents and brake fluids.

A life cycle evaluation of PC requires an assessment of all potential impacts associated

with its production and use. Section 2.1 summarizes the steps involved in the manufacture of PC, starting with the extraction and processing of natural gas to the manufacture of the final PC product. Section 2.2 contains summaries of case histories regarding the use of PC in paint and depainting operations, as well as other applications that provide similar exposure scenarios.

2.1 Production

A description of the process required to manufacture PC is presented in Thomas and Franklin (1996). Propylenes and other olefins are produced through the thermal cracking of saturated hydrocarbons such as ethane, propane, naphtha, and other gas oils. Production begins when hydrocarbons and steam are fed into a cracking furnace. After being heated to temperatures around 1,000 °C, the cracked products are quenched in heat exchangers. Fuel oil is separated from the main gas stream in a multistage centrifugal compressor. The main gas stream then undergoes H₂S removal and drying. Propylene is combined with a tert-butyl hydroperoxide and alcohol mixture at a rate of 2 to 6 moles of propylene per mole of hydroperoxide. This mixture is reacted to nearly 100 percent conversion of the hydroperoxide over a catalyst usually made of molybdenum. Propylene and propylene oxide are separated from the product in distillation columns.

Propylene carbonate is produced by the reaction of propylene oxide with carbon dioxide over a tetraethyl/ammonium bromide catalyst. The total energy required to produce 1,000 lb of PC from raw material acquisition through production equals 14,639,000 Btu for material resource energy, 10,788,000 Btu for process energy, and 612,000 Btu for transportation energy. A flow diagram of this process is shown in Figure 1 and on page A-15 in *Life Cycle Assessment for the PC Blend 2 Aircraft Radome Depainter* (Thomas and Franklin, 1996).

The composition of paint strippers using PC are defined in U.S. Patent Nos. 5,575,859 and 5,629,277. Patent No. 5,281,723, titled *Propylene Carbonate Recovery Process*, describes a method devised to recover a cyclic alkylene carbonate, such as PC, from an effluent stream of carbonate, water, and polymeric solids. The effluent would be typically processed using a method in which the cyclic alkylene carbonate removes an organic photoresist material from a substrate.

2.2 Use

The properties of PC make it suitable for use in painting and depainting and other industrial stripping and cleaning operations and as a chemical reagent. This section contains summaries of case studies conducted using PC in painting and depainting operations, as well as in other applications that entailed similar exposure scenarios to the painting and depainting operations. Complete case studies are provided in Appendix A. Summaries of case studies are provided, not the complete reports or project summaries.

Pollution Prevention Demonstration and Evaluation of Paint Application Equipment and Alternatives to Methylene Chloride and Methyl Ethyl Ketone (J.M. Elion et al., EPA/600/SR-96/117, October 1996).

This research provides results of a demonstration of PC as a possible alternative to MEK. The demonstration was conducted at the Marine Corps Logistics Base in Albany, GA. Activities involving the cleaning of paint application equipment with MEK were selected to demonstrate possible PC substitution. For this demonstration, a blend of 40 percent PC and 60 percent benzyl alcohol (BA), by weight, was chosen to replace MEK. This choice was based on the results of laboratory screening, materials compatibility, and paint removal efficiency tests. Based on the demonstration, PC/BA cleaned green CARCs from the pumps as well as MEK, and it cleaned epoxy primers better than MEK. If employed, this substitution would potentially reduce hazardous air pollutants (HAPs) at the base by 21 percent from 1992 levels. Although no capital investment was required, the cost for the PC/BA blend was higher than for MEK, but the higher cost may be offset by cleaner recovery and reclamation and further waste reduction.

Substitutes for Methylene Chloride Paint Strippers--Performance Evaluation and Adaptation to Aircraft Maintenance Procedures (G.E. Baker and E.F. Hollins, Pacific Environmental Services, Inc., Presented at the Air & Waste Management Association's 90th Annual Meeting & Exhibition, June 8-13, 1997, Toronto, Ontario, Canada).

The pollution prevention division of the Oklahoma City Air Logistics Center at Tinker Air Force Base (TAFB), an Air Force Material Command (AFMC) installation, investigated possible PC blends to eliminate the use of methylene chloride-based strippers from its depainting operations. As part of the study, bench- and full-scale tests were conducted. None of the PC blends passed the consistency or flow tests based upon visual observation of surface wetting and filming properties. Flash points for all but one of the blends were below 200 °F. One blend failed the corrosion tests on magnesium.

Project Summary Life Cycle Assessment for PC Blend 2 Aircraft Radome Depainter (R. Thomas and W.E. Franklin, EPA/600/SR-96/094, September 1996).

The purpose of this research effort was to conduct an LCA on a potential replacement solvent blend, PC Blend 2 (PC2), for aircraft radome depainting at the Oklahoma City Air Logistics Center at TAFB. PC2 is comprised of 50/25/25 weight percent N-methylpyrrolidone (NMP), dibasic ester (DBE), and PC. The study was designed to conduct the LCA with respect to energy requirements, solid wastes, atmospheric emissions, and waterborne wastes associated with and resulting from the production, use, and disposal of PC2 depainting solvent. Mention of this case study here provides the reader with information concerning an LCA conducted on a PC blend.

Project Summary Radome Depainting Evaluation at Tinker Air Force Base (EPA/600/SR-95/079, June 1995).

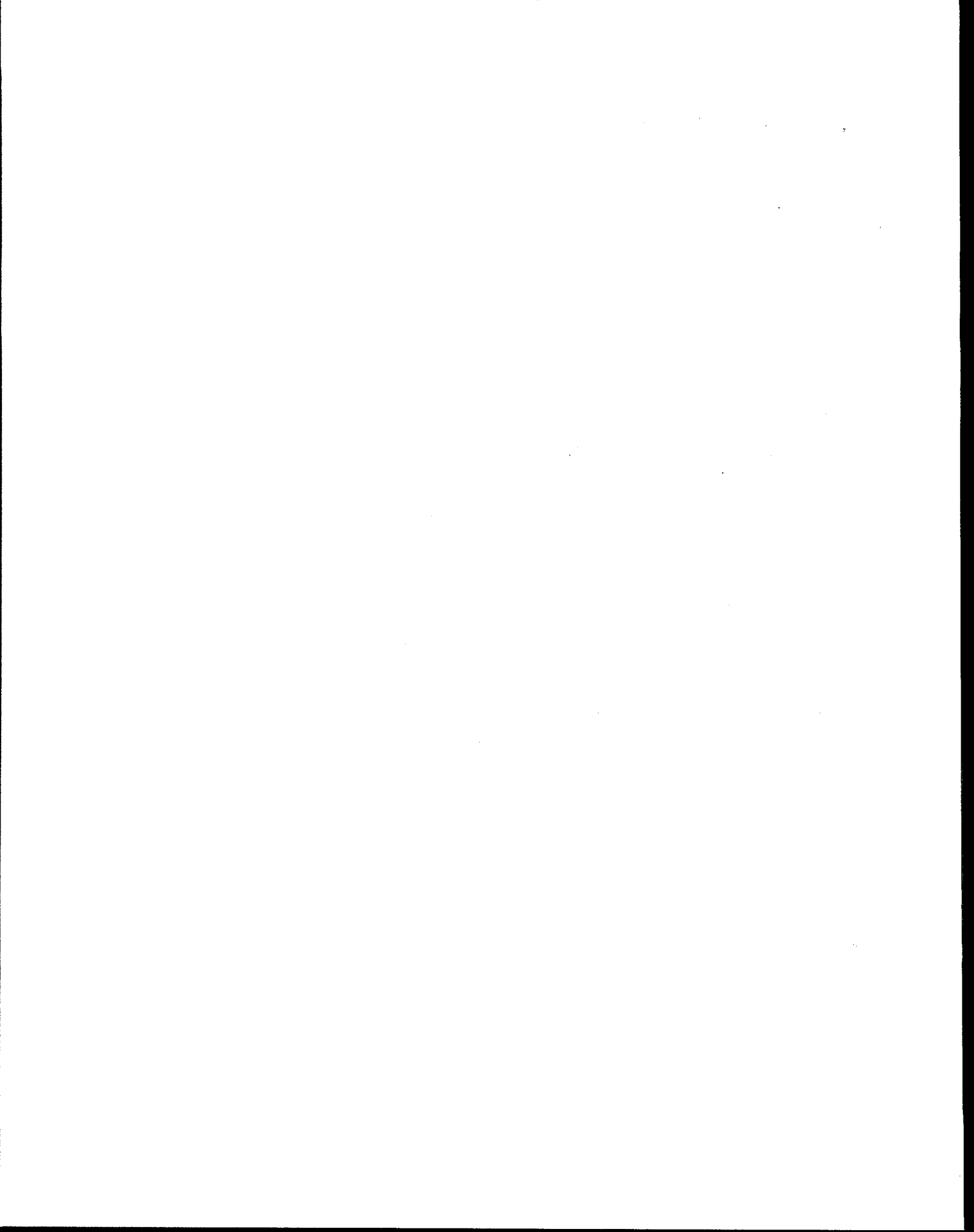
This research describes a test program to determine the feasibility of using 10 possible alternative paint-stripping solvents, 5 of which were PC blends, that were less hazardous to the environment and public health than MEK. Testing involved immersing a 2- by 2-in square of an aircraft radome (a fiberglass and epoxy or polyester composite material, in a honeycomb structure) coated with a primer, a polyurethane rain-erosion coating, and a polyurethane antistatic topcoat, in a beaker of the selected solvent. Parameters evaluated included a visual assessment of the degree of attack (percent removal) on the coating in 0.5-, 1-, 2-, 4-, 8-, and 24-h increments.

Test results indicated that several of the solvents stripped the paint quicker and more efficiently than MEK. Although visual examination showed no damage to the substrate, there was some concern about potential substrate damage due to the complete and aggressive removal of all three coats. Three of the solvent PC blends completely removed the top two coats while leaving the primer untouched. Leaving the primer layer intact is considered a suitable alternative to complete paint removal. This process would ensure that the substrate is not damaged during the depainting operation. Additionally, it may provide some economic advantages in material and manpower savings.

Project Summary Evaluation of Propylene Carbonate in Air Logistics Center (ALC) Depainting Operations (S. Rosenthal and A.M. Hooper, Foster Wheeler Enviresponse, Inc., Edison, NJ, EPA/600/SR-94/176, September 1994).

This report summarizes a two-phase, laboratory-scale screening study evaluating depainting solvent blends of PC as possible replacements for MEK in aircraft radome depainting operations. The first phase of screening evaluated the performance of solvent blends from Texaco Chemical Company containing varying percentages of PC, NMP, DBE, and other organic solvents. Performance was compared to that of MEK based on paint removal time and visual estimation of the amount of paint removed without any visible substrate damage. The best performing blend was PC2, containing 25/50/25 percent PC/NMP/DBE.

This solvent blend was then compared with MEK during the second phase of testing to measure paint removal time and efficiency, paint adhesion, flexural properties, weight change of the substrate after paint removal, and hardness of the unpainted substrate test panels. Results showed that PC2 performed favorably in comparison with MEK in removing paint from fiberglass and epoxy test panels and in subsequent paint adhesion tests, despite a possible indication of substrate damage.



3.0 Impact Categories

A life cycle evaluation of the potential impacts of PC requires that impacts both to the environment and to human health be considered. To assist in guiding the search for information related to PC, impact categories and subcategories were established. Numerous impact categories have been proposed for life cycle impact assessment, and most LCAs to date have selected from these previous efforts in lieu of defining their own impact categories. However, impact categories are typically selected so that the goals of the study may be satisfied.

This section lists the categories and subcategories of impacts to the environment and to human health that were selected as starting points for the evaluation of PC. For each category and subcategory, quantitative and qualitative impact information was searched for and compiled under each category as appropriate. Any additional impacts found that were not part of the original listing were subsequently added.

3.1 Ecological Impacts

Potential ecological impacts of PC as used in painting and depainting operations result primarily from the production, use, and disposal stages of its life cycle, where emissions are released directly into the environment. Examples of activities that might result in environmental impacts could include the extraction and processing of natural gas, the volatilization of PC during use, or the leaching of residual PC into the soil or ground water. To establish a baseline set of ecological impact categories for this research, LCA guidance documents and case studies were consulted. The resulting list of impact categories is shown in Table 3-1. The impacts have been categorized by their mechanism of action, mainly whether they result from chemical or nonchemical pollutants or from resource depletion.

3.2 Human Health Impacts

Potential human health impacts of PC as used in painting and depainting operations result primarily from the use stage of its life cycle, where workers may be directly exposed to PC emissions. Additional human health impacts may result from emissions released during the production and disposal stages of the life cycle. To establish a baseline set of human health impact categories for this research, LCA guidance documents and case studies were consulted. The resulting list of impact categories is shown in Table 3-2. The impacts have been categorized by their mechanism of action, mainly whether they result from chemical or nonchemical pollutants.

Table 3-1. Ecological Impact Categories Related to Chemical And Nonchemical Stressors and Resource Depletion

Chemical	Nonchemical	Resource Depletion
<ul style="list-style-type: none"> • Global warming • Ozone depletion • Acid deposition • Photochemical oxidant formation • Tropospheric ozone • Aquatic toxicity • Eutrophication • Visibility alterations • pH alterations • Chemical/biological content alteration • Oxygen depletion • Aquifer contamination • Land use 	<ul style="list-style-type: none"> • Ionizing radiation • Heat • Noise • Environmental disturbance <ul style="list-style-type: none"> -habitat alteration -physical change to water -physical change to soil • Regional climate change • Species change <ul style="list-style-type: none"> -composition -total diversity 	<p><i>Nonrenewable</i></p> <ul style="list-style-type: none"> • Fossil fuels • Minerals <p><i>Renewable</i></p> <ul style="list-style-type: none"> • Water • Renewable energy • Agricultural resources • Wilderness resources

Table 3-2. Human Health Impact Categories Related to Chemical and Nonchemical Stressors

Chemical	Nonchemical
<ul style="list-style-type: none"> • Human carcinogen • Inhalation toxicity • Irritant (eye, lung, skin, gastrointestinal [GI]) • Respiratory system effects • Central nervous system effects • Mutagenicity • Developmental toxicity • Allergenicity • Blood dyscrasias • Odors • Cardiovascular system effects • Reproductive effects • Behavioral effects • Bone effects • Renal effects 	<ul style="list-style-type: none"> • Heat • Noise • Light • Nuisance

4.0 Data Review

A joint literature search was conducted for PC and NMP. Both of these chemicals are components of PC2, which is used in depainting. This section discusses the literature search and summarizes the available information on PC's physical and chemical properties, environmental fate and transport, and toxicity. However, Tables 4-1 and 4-2 are inclusive of both NMP and PC.

4.1 Sources

Research Triangle Institute (RTI) conducted an extensive literature search for NMP and PC. In addition to searching online databases, manufacturers were contacted, government reports were located, and an Internet search was conducted. Results of the literature and Internet searches are summarized in the following sections.

4.1.1 Literature Search

A literature search was performed using the databases listed in Table 4-1. The databases were searched from 1990 to the present using N-methylene-pyrrolidone and propylene carbonate as key words. The number of relevant articles found in each database are listed in Table 4-1.

Table 4-1. Literature Search for NMP And PC

Name of Database	Database Topic	Number of Articles Found
MEDLINE	Health and medicine	6
Enviroline	Environmental subjects	1
Wilson Applied Science and Technology Abstracts	Science and technology	54
Pollution Abstracts	Pollution topics	1
Environmental Bibliography	Environmental subjects	6
NTIS: National Technical Information Services	Government technical reports	2
Ei Compendex	Engineering	86
World Surface Coatings Abstracts	Coating, paints, inks	14

A second search was performed using the following key words related to NMP and PC: greenhouse, global warming, acid rain, smog, photochemical, ozone, air dispersion, air aging, air transport, aquatic, plant life, eutrophication, visibility, weather, thermal, alterations, oxygen depletion, aquifer, thermal change, and oxygen depletion. Table 4-2 lists the databases searched, the dates searched, and the number of articles found in each database.

Table 4-2. Specific Topic Literature Search for NMP and PC

Name of Database	Database Topic	Number of Articles Found	Dates Searched
Meteorological and Geoastrophysical Abstracts	Meteorological and environmental subjects	0	June 1970-1997
Enviroline	Environmental subjects	2	August 1975-1997
GeoArchive	Geosciences	0	August 1974-1997
WATERNET	Water topics	0	1971-1997
Water Resources Abstracts	Water resource topics	8	August 1967-1997
GEOBASE	Ecology	0	August 1980-1997
BIOSIS	Biological abstracts	22	September 1969-1997
Aquatic Sciences and Fisheries Abstracts	Marine and freshwater environments	0	September 1979-1997
Environmental Bibliography	Environmental subjects	6	October 1974-1997
MEDLINE	Health and medicine	14	November 1966-1997
CANCERLIT	Cancer	3	September 1975-1997
PsycINFO	Psychology, health	0	October 1967-1997
TOXLINE	Toxicological literature	34	August 1965-1997
EMBASE	Biomedical literature	49	August 1974-1997
IAC Health and Wellness Database	Health	1	1976-1997

The EPA Office of Pollution Prevention and Toxics (OPPT) provided the following reports relevant to PC:

- *Initial Screening of Chemical Ingredients and Substitutes in Consumer and Small Shop Paint Stripper Formulations.*

- *Consumer/Small Shop Paint Stripping Use Cluster AR-161 Risk Management Report Public Comment Draft.*

The U.S. Coast Guard is currently evaluating alternatives to using methylene chloride for small aircraft paint stripping in a Design for the Environment project. No information on PC was available at the time of publication.

Huntsman Specialty Chemical in Houston, TX, was contacted for information. Because of proprietary agreements, the names of clients could not be provided. Huntsman was able to send the following information:

- *Test Procedures for the Degradability and Bacterial Toxicity of Chlorinated Hydrocarbon Replacements* (Kayser et al., n.d.).
- *Permeability of Commercial Solvents Through Living Human Skin* (Ursin et al., 1995).
- *Propylene Carbonate: Toxicity Testing Summary* (Huntsman, n.d.) and *Jeffsol™ Ethylene and Propylene Carbonates* (Huntsman, 1994).

4.1.2 Internet Search

Several Internet searches were conducted to gather environmental profile data for PC. The following keywords were used for the searches: methylene chloride substitution, methyl ethyl ketone substitution, propylene carbonate, solvent replacement, solvent substitution, depainting solvents, painting solvents, aircraft depainting, paint removal, health effects (propylene carbonate), environmental effects (propylene carbonate), ecological effects (propylene carbonate), radome depainting, paint stripping, toxicity (propylene carbonate), aerospace painting, and aerospace depainting. Table 4-3 lists the Internet sites that were found for PC.

4.2 Physical and Chemical Properties

Propylene carbonate is a near odorless and colorless solvent. It has a high dielectric constant, low vapor pressure, high chemical stability, and low viscosity. Its molecular formula is $C_4H_6O_3$. PC has a high boiling point and a low coefficient of friction (Clark et al., n.d.). Table 4-4 presents the physical and chemical properties of PC.

Table 4-3. Internet Searches for PC Environmental Profile Data

Title	Address	Type of Information
Chemfinder	http://chemfinder.camsoft.com	Physical and chemical properties
National Center for Manufacturing Sciences	http://solvdb.ncms.org	Physical and chemical properties, health and safety data, regulatory information, environmental fate data
University of Utah Material Safety Data Sheet (MSDS) Archive	http://www.chem.utah.edu/MSDS/P/PROPYLENE_CARBOONATE	Physical and chemical properties, toxicity data, reactivity data
Solvent Handbook Database System--Product Data for ARCONATE 1000 PROPYLENE CARBOONATE	http://wastenot.inel.gov/shds/product_1/3.html	Physical and chemical properties
Chemical Sampling Information	http://www.osha-slc.gov/ChemSamp_data/CH_264450.html	Physical and chemical properties
National Institute of Standards and Technology (NIST) Chemistry WebBook	http://webbook.nist.gov/chemistry	Thermochemical and thermophysical properties
Welcome to Fisher Scientific	http://www.fisher1.com/fb/itv?2..f97.4.fsc95_21.655.1...	Physical and chemical properties, hazards identification, toxicological information, regulatory information
The Environmental Chemicals Data Information Network (ECDIN) Data Bank	http://ulisse.etoit.eudra.org/cgi-bin_ecd/inter_query	Identification, physical and chemical properties, production and use, legislation and rules, occupational health and safety, toxicity, concentrations and fate in the environment, detection methods, hazards and emergency response
National Fire Protection Association (NFPA) Chemical Hazard Labels	http://www.orcbs.msu.edu/chemical/nfpa/hazardinformation(p-r).html	Populations at risk (workers)
Environmental Health Perspectives Search Form	http://ehpnet1.niehs.nih.gov/docs/ehp_search.html	Toxicity

(continued)

Table 4-3. (Continued)

Title	Address	Type of Information
Environmental Science Center Experimental Log P (octanol/water partition coefficient) Database	http://esc.syrres.com/~ESC/database.htm	Experimental log p (octanol/water partition coefficient)
Physical Properties Database (PHYSPROP)	Commercially available database	Chemical structures, names, and physical properties
Environmental Fate Database (EFDB)	Commercially available database	Environmental fate and exposure data including adsorption, bioconcentration, biodegradation, dissociation constant, effluent concentrations, monitoring, occupational concentrations, and photo-oxidation
Toxic Substances Control Act Test Submission (TSCATS) Database	Commercially available database	Unpublished technical reports submitted by industry concerning health effects, environmental effects, and environmental fate
Chemical Pointer File	Commercially available database	Regulatory information, toxicity, environmental fate and transport
Compilation of Ozone Depletion Potentials (ODP) and Global Warming Potentials (GWP)	http://esc.syrres.com/~ESC/ODPGWP.htm	N/A
Atmospheric Oxidation Database	http://esc.syrres.com/~ESC/aopexp.htm	N/A
DefenseLINK (Links to Army, Air Force, Navy, and Marine Corps homepages)	http://www.defenselink.mil	N/A

N/A = No information was available for PC at this site.

Table 4-4. PC Physical and Chemical Properties

Physical State	Liquid
Appearance ^a	Clear colorless liquid
Odor ^a	Slight odor
Boiling point ^b (°C, 760 mmHg)	241.9
Coefficient of expansion, cm ³ /cm ³ /°C	0.00096
Density, lb/gal	10.05 (20 °C)
Dielectric constant, esu	65.0 (25 °C)
	62.5 (36 °C)
	56.9 (40 °C)
Dipole moment, 40 °C, debye units	4.98
Evaporation rate (n-BuAc = 1)	<0.01
Fire point, °F	280
Flash point, °F	275
Freezing point, °C	-49.2
Hansen solubility parameters, cal ^{1/2} cm ^{-3/2}	13.3, Total
	9.8, Dispersive (nonpolar)
	8.8, Polar
	2.0, Hydrogen bonding
Heat capacity, cal/g/°C	0.389 (15 °C)
	0.408 (50 °C)
	0.434 (100 °C)
	0.460 (150 °C)
Heat of combustion, cal/g	3,396
	347 (kcal/mol)
Heat of fusion, cal/g	18
Heat of vaporization, cal/mol	17,700 (50 °C)
	15,200 (100 °C)
	13,300 (150 °C)
	12,000 (200 °C)
Molecular weight	102.9
Pour point, °F	-100
Refractive index	1.4210 (n ^{20D})
Specific gravity	1.2057 (20/4 °C)

(continued)

Physical State	Liquid
Thermal conductivity, 41 °C	0.12 Btu/(hr)(ft ²)(°F/ft) 49.6 x 10 ⁻⁵ cal/(s)(cm ²)(°C/cm)
Viscosity, cs	33.5 (-40 °C) 10.5 (-20 °C) 4.8 (0 °C) 2.8 (20 °C) 1.9 (40 °C)
Specific gravity ^c	1.1951
Viscosity (cP) ^c	2.530
Vapor pressure (mmHg) ^c	1.2
Surface tension (dynes-cm ²) ^c	41.39
Flash point (Fahrenheit) ^c	269.6
Explosion limit % (Upper) ^a	14.3
Explosion limit % (Lower) ^a	1.8
Evaporation rate (BuAc = 1) ^c	0.005
Solubility (water, % weight) ^d	Moderate (1 to less than 10 percent)
Typical pH ^d	5.5 to 7.5
Autoignition temperature (Fahrenheit) ^a	950
Reactivity	Chemical stability: stable under normal temperatures and pressures. Incompatible with strong oxidizing agents, acids, bases, and reducing agents.

^a Fisher Scientific, 1997.

^b Clark et al., n.d.

^c National Center for Manufacturing Sciences, 1996.

^d ARCO Chemical Company, 1995b.

4.3 Environmental Fate and Transport

Very little information concerning the environmental fate and transport of PC was found. ARCO (1995a) provided a summary of the mobility, degradability, and bioaccumulation of PC as follows: "leaching to water may occur; however, no data were available on soil to air or water to air mobility." Based on the available physical and chemical properties, evaporation from soil and water would be slow. PC may decompose in aqueous solutions that vary from a neutral pH and in water with the transient formation of propylene oxide. No data were available on bioaccumulation or biomagnification (ARCO, 1995a).

Propylene carbonate was studied to determine its aerobic degradability and bacterial toxicity (Kayser et al., n.d.). Concentrations of 250 mg/L and 2,500 mg/L were selected based on typical concentrations detected in wastewater. Propylene carbonate was degraded over the entire range of test concentrations, achieving 80 percent degradation 10 days after an initial lag phase of 1 day. The authors concluded that PC could be considered as being very readily biodegradable.

Nevertheless, a patented method of transforming alkylene carbonates, such as PC, into more environmentally manageable end products is described in *Chemical Pre-Treatment and Biological Destruction of Propylene Carbonate Waste Streams Effluent Streams to Reduce the Biological Oxygen Demand Thereof* (U.S. Patent No. 5,275,734). The invention was specifically designed for treatment of PC used as a developer and as a stripping solvent for photoresist materials. The effluent stream is treated to hydrolyze PC to a relatively biodegradable intermediate (i.e., propylene glycol), which can then be biodegraded (Shurtleff and Unger, 1994).

4.4 Toxicity

The toxicity of PC has not been extensively studied. Huntsman (n.d.) prepared a toxicity testing summary in an unpublished report, and another source concluded that PC was safe to use as a cosmetic ingredient at concentrations up to 20 percent (Final Report on the Safety Assessment, 1987). The MSDS sheet identifies skin, eye, and respiratory irritation as possible toxic effects and indicates that no signs or symptoms are expected following ingestion (ARCO, 1995b). The available toxicity data are reviewed below.

PC is also blended with other chemicals to form other depainting formulations. One of these is PC Blend 2, which consists of 25 percent PC, 50 percent NMP, and 25 percent DBE. DBE includes dimethyl adipate, dimethyl succinate, and dimethyl glutarate.

A separate environmental profile was completed for NMP as part of this project (RTI, 1998). In general NMP has a low order of acute and chronic toxicity; however, it is a skin and eye irritant and is well absorbed through the skin. NMP is not likely to be carcinogenic or mutagenic but has caused reproductive and developmental effects in laboratory rats exposed to relatively high concentrations through skin application or inhalation.

Very little toxicity data are available for the DBE chemicals. Like NMP, dimethyl adipate is an irritant and a reproductive/developmental toxicant in laboratory rats (U.S. EPA, 1996). According to the MSDS for dimethyl adipate and dimethyl succinate, these chemicals are combustible and are incompatible with acids, bases, oxidizing agents, or reducing agents. Combustion and decomposition products include carbon monoxide and carbon dioxide.

4.4.1 Human Data

Final Report on the Safety Assessment of Propylene Carbonate, 1987.

A number of clinical studies were conducted in hundreds of human volunteers to test whether or not PC and PC-containing cosmetic preparations (underarm stick, cream blush, gels, eyeliner, lipslicker, etc.) caused skin irritation or sensitization. Undiluted PC caused moderate skin irritation, aqueous solutions containing 5 to 10 percent PC caused no irritation or sensitization, and cosmetic products containing 0.54 to 20 percent PC were essentially nonsensitizing but caused some skin irritation. One product containing 20 percent PC appeared to produce a low-level photoallergic reaction in 1 of 25 people tested.

Huntsman, 1994. JEFFSOL™ Ethylene and Propylene Carbonates.

Dermal patch testing in humans using 5 percent and 10 percent aqueous solutions of JEFFSOL PC did not produce irritation or sensitization.

4.4.2 Laboratory Animal Data

Huntsman, n.d.. Propylene Carbonate: Toxicity Testing Summary.

Huntsman prepared a summary of studies investigating PC's teratogenicity, subchronic oral and inhalation toxicity, neurotoxicity, and dermal carcinogenicity.

Teratogenicity: Twenty-seven dams (Sprague-Dawley rats) per group were orally exposed by gavage to 1,000, 3,000, and 5,000 mg/kg/d of PC on days 6 through 15 of gestation. A control group was given deionized water. The study was terminated on day 20 of gestation with a complete examination of the uterine contents. It was found that exposure to PC at concentrations up to 5,000 mg/kg/d did not induce developmental toxicity; however, some maternal toxicity was observed in the high-dose group (decreased body weight gain and food consumption).

Subchronic (90-day) Oral Toxicity: Sprague-Dawley rats were given 1,000, 3,000, and 5,000 mg/kg/d of PC by gavage for 90 days. A control group was given deionized water. In addition, a high-dose recovery group was included to determine the persistence and reversibility of any toxic effects. The recovery group was followed from day 90 of the study through day 118. Thirty rats per group (15 of each sex) and 20 rats in the recovery group were studied. An interim sacrifice of 10 rats per group, excluding the recovery group, was conducted on day 30. At sacrifice, all animals were necropsied and grossly examined. Blood samples were collected for clinical chemistry and hematology measurements, and an ophthalmological examination was performed. A full screen of potential target organ tissues was fixed for histopathological examination. No consistent dose-related findings were reported following necropsy or histopathological examination. Results of the test showed that PC at concentrations of up to 5,000 mg/kg/d did not induce any significant toxic effects.

Subchronic (90-day) Inhalation Toxicity: Fischer 344/CDF rats were exposed to 100, 500, or 1,000 mg/m³/d of aerosol PC over a 90-day period. Negative controls were exposed to filtered

air on the same exposure regimen. Groups consisted of 30 rats (15 per sex) with an additional 20 animals per group to study acute neurotoxicity (see below). Hematology, clinical chemistry, and urinalysis were normal in all test groups. No other significant signs of toxicity were noted, with the exception of some periocular swelling in the high- and mid-dose groups. No systemic toxicity was reported.

Neurotoxicity: An additional 20 rats per group were studied concurrently with the subchronic inhalation study to investigate acute and subchronic neurotoxicity. For the acute study, rats received a single 6-hour exposure to PC aerosol. Observation at 1 hour and at 24 hours after exposure revealed that PC concentrations of 1,000 mg/m³ or less do not produce behavioral alterations in rats. In addition, standard neurobehavioral tests and motor activity were examined in groups of rats following 6 and 13 weeks of exposure. No behavioral alterations were noted in any exposure group.

Dermal Carcinogenicity: Fifty microliters (μL) of undiluted PC was applied twice a week to the shaved backs of 50 male mice for 104 weeks. Negative controls included nontreated animals and animals treated with mineral oil; positive controls included animals treated with 0.05 percent benzo(a)pyrene in acetone. A total of 10.4 mL PC was applied to each animal over the course of the study. No test-related deaths were observed during the course of the study. No consistent body weight changes, tumors, or significant dermal effects were noted during the course of the study.

Final Report on the Safety Assessment of Propylene Carbonate, 1987.

This report summarized laboratory animal data on acute toxicity, skin and eye irritation, acute and subchronic dermal toxicity, inhalation toxicity, and mutagenicity. Propylene carbonate is typically used at concentrations ranging from <0.1 percent to 5.0 percent in cosmetics. Various studies were conducted to assess the safety of PC use in cosmetics. Acute oral toxicity has been studied in rats by giving test animals single doses of undiluted PC and cosmetic formulations dissolved in corn oil or mineral oil. In most cases, animals were observed for 14 days following exposure. These tests indicate a low order of acute oral toxicity, with a reported lethal dose, 50 percent kill (LD₅₀) in rats of 29.1 g/kg. A few animals receiving cosmetic preparations at 5 g/kg PC exhibited some signs of toxicity (sedation, dyspnea, poor grooming, red stools, weight loss, congested kidneys, and GI symptoms).

Undiluted PC produced minimal to moderate ocular irritation and slight skin irritation in studies with rabbits. Rabbits treated with 2 mg/kg of undiluted PC on abraded skin experienced slight erythema; however, no lesions were observed at necropsy. In oral toxicity testing, salivation was noted in rats given undiluted PC in a single 5-g/kg oral dose. Undiluted PC was nontoxic to dogs and guinea pigs by inhalation but caused rhinorrhea and diarrhea in rats. Daily application of 10.5 or 17.5 percent PC in physiological saline to the skin of rats for 1 month produced hyperkeratosis and an increase in the number of basal epithelial cells at the treatment site. Mutagenicity was tested with several strains of *Salmonella typhimurium* (Ames assay) with

and without metabolic activation and in rat hepatocytes. These tests indicate that PC is not mutagenic. On the basis of these data, PC was determined to be a safe cosmetic ingredient in present concentrations and practices of use.

Huntsman, 1994. JEFFSOL™ Ethylene and Propylene Carbonates.

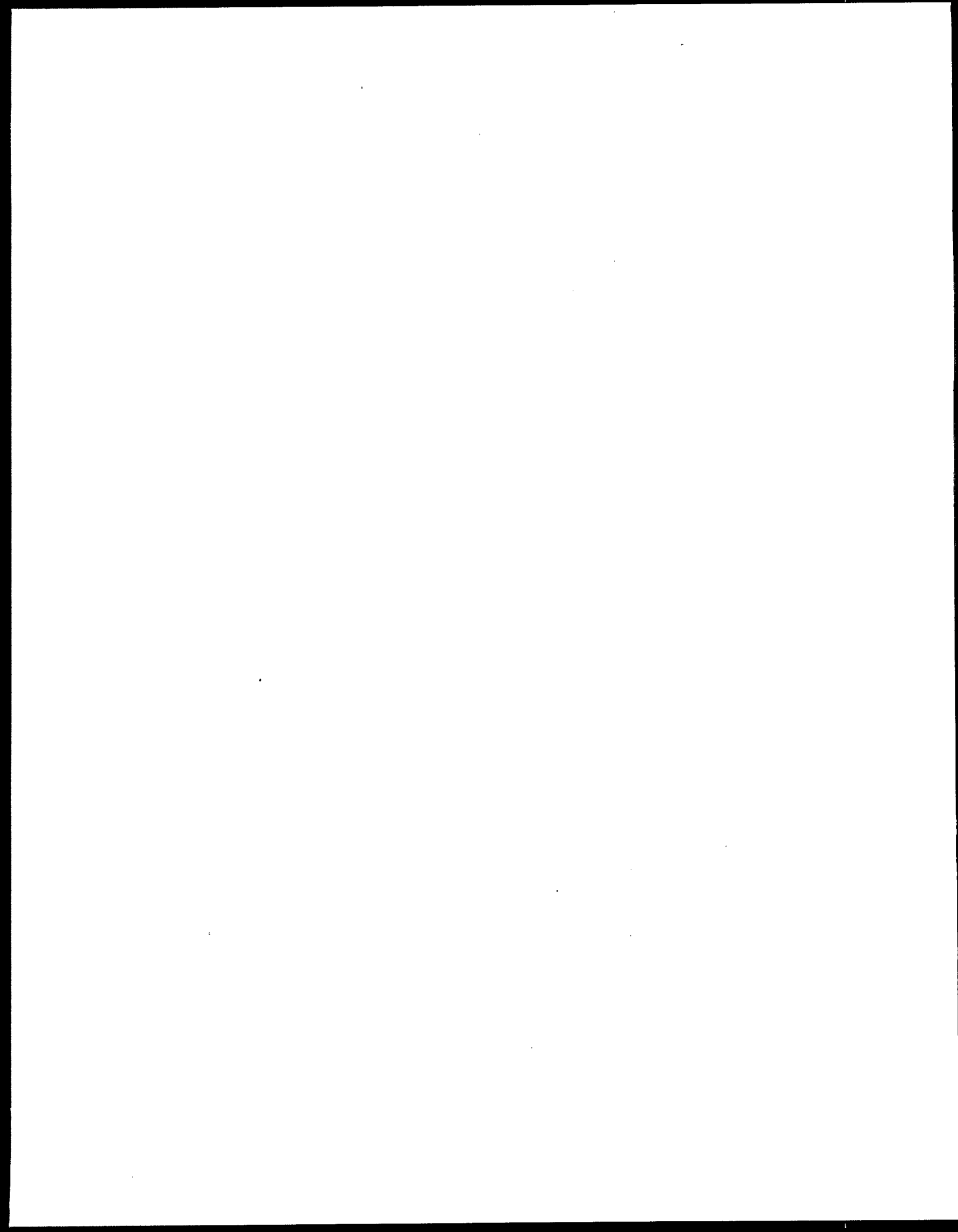
According to Huntsman, JEFFSOL PC was found to be practically nontoxic by single oral or dermal exposures. Acute studies showed JEFFSOL PC to be minimally irritating to the skin of rabbits, while the application of the undiluted product to their eyes resulted in marked irritation of conjunctival tissues within 24 hours after administration. This irritation subsided after 48 hours in most animals. Dermal sensitization studies using guinea pigs were negative. In a subchronic toxicity study, rats exposed to JEFFSOL PC at aerosol concentrations of up to 1,000 mg/m³ over 90 days showed signs of ocular irritation only. In a chronic study conducted over a 2-year period, PC was applied dermally two times a week to mice without removing the material between applications. The results indicate that the product is not dermally carcinogenic and produced no evidence of any abnormal dermal lesions or systemic toxicity from the exposure. In a developmental toxicity study, pregnant rats were given oral doses of PC with concentrations up to 5,000 mg/kg/d over the period of fetal development. Evidence of maternal toxicity was apparent in the high-dose group; however, there were no significant findings with regard to fertility parameters, viable and nonviable fetuses, fetal sex distribution, or fetal body weights. In addition, no fetal malformations were observed. On the basis of these studies, Huntsman concluded that PC would not cause serious injury from amounts that might be accidentally ingested, spilled on the skin, or inhaled.

4.4.3 Toxicokinetics

No information was found on the distribution, metabolism, and excretion of PC. One study was found that investigated dermal absorption.

Ursin et al., 1995. Permeability of Commercial Solvents Through Living Human Skin.

A procedure to measure the steady-state rate of permeation of commercial solvents through living human skin was used on human female skin. The skin was removed from healthy females during plastic surgery of the breast. The samples were thinned by removing the dermal tissue from the epidermis and then stretched to a thickness of 300 to 600 μ m. Each piece of surgically removed skin usually provided sufficient material to run nine permeation experiments. The permeability rate of PC was determined to be 0.7 g/m²h compared to a permeability rate for water of 24 g/m²h. Therefore, it can be concluded that PC is not readily absorbed through the skin.



5.0 Impact Assessment

No specific data were available regarding environmental impacts of PC releases. The U.S. EPA (1996) has prepared an LCA of PC2 (a mixture of 50 percent NMP, 25 percent DBE, and 25 percent PC).

5.1 Human Populations at Risk

U.S. EPA (1996) reported that air emissions from PC2 would not be expected to pose a hazard to workers or nearby residents based on comparison of modeled air concentrations to recommended occupational standards. A safety assessment conducted for PC because of its use in various cosmetic products concluded that PC-containing cosmetics posed little hazard. Based on the low order of toxicity, low rate of skin absorption, low volatility, and low environmental persistence, PC poses minimal risk to workers and residential populations.

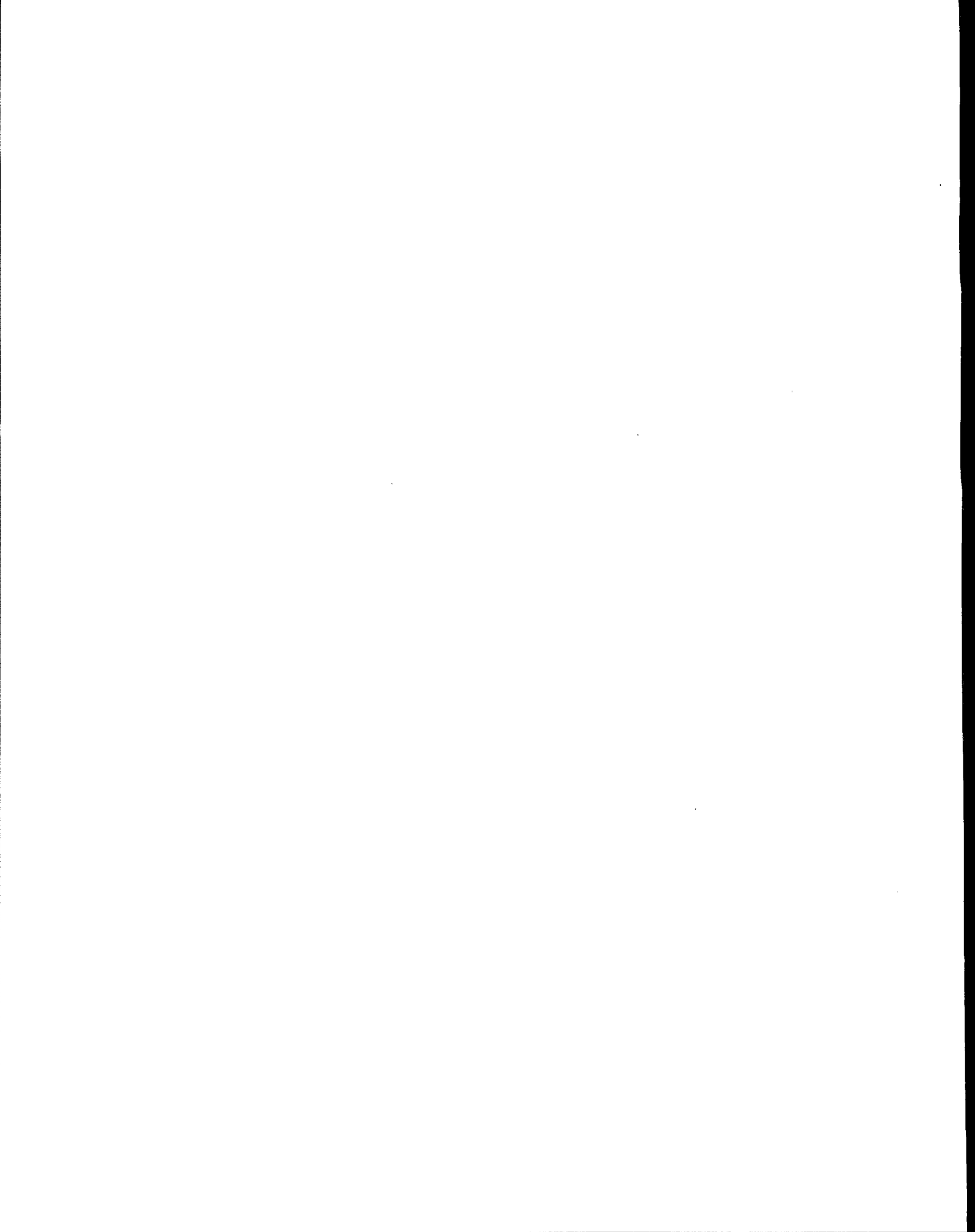
5.2 Natural Resources/Ecosystems

The LC_{50} values for the following species have been determined (ARCO Chemical Company, 1995b):

1. *Lepomis Macrochirus* -- >5 mg/L (24 hours)
2. Goldfish -- >5 mg/L (24 hours)
3. Trout -- >5 mg/L (24 hours).

No relevant data have been identified for soil organisms or plants and terrestrial animals (ARCO Chemical Company, 1995a). The urban ozone formation potential for PC ($C_2H_4 = 1$) is 0.08 (National Center for Manufacturing Sciences, n.d.).

Of the list of ecological impact categories presented in Section 3.1, limited data were available for PC's aquatic toxicity and ozone formation potential. Data needs include information concerning its global warming potential, visibility alterations, weather alterations, pH alterations, chemical/biological content alterations, aquifer contamination, land use, and natural resource depletion.



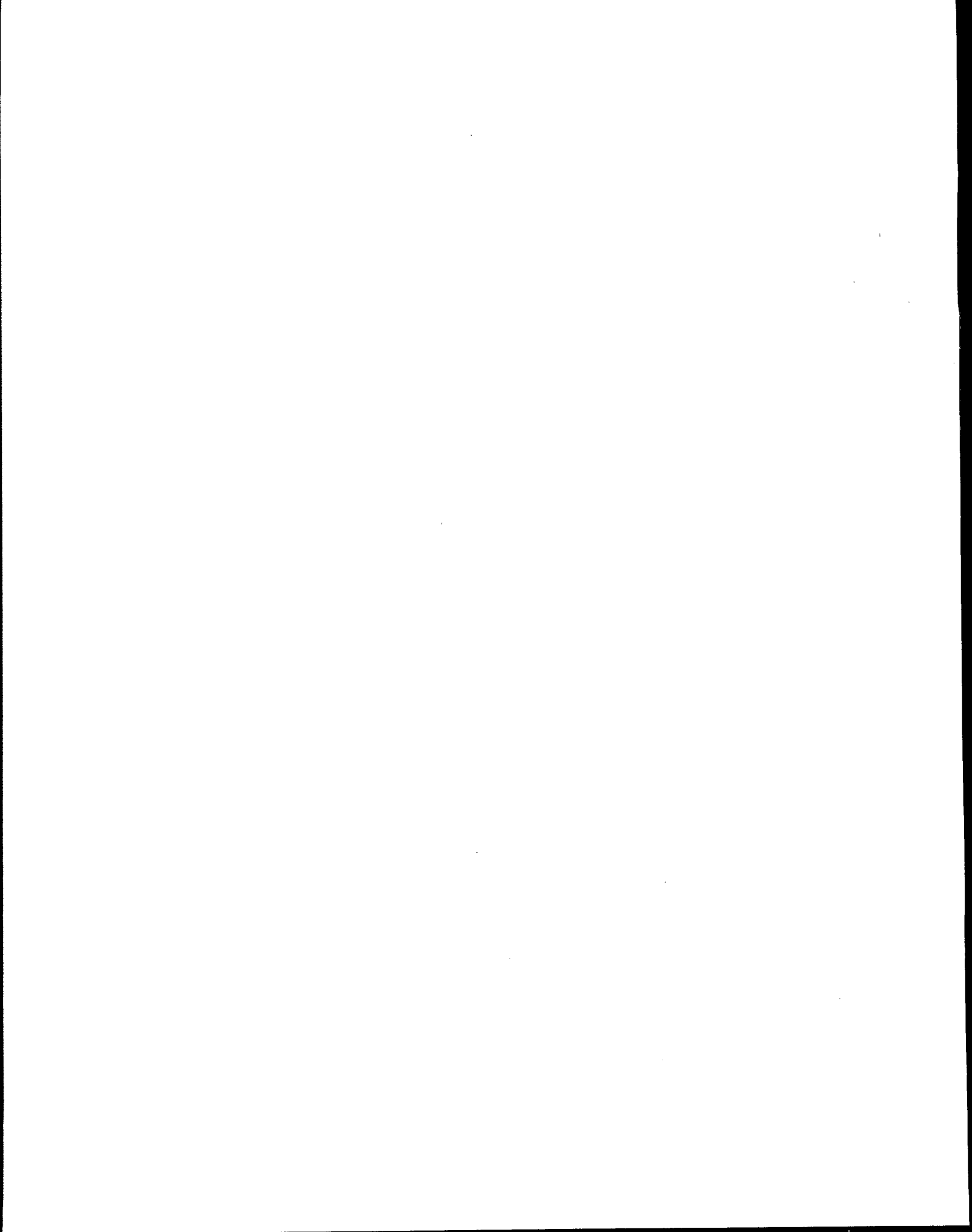
6.0 Environmental Regulations

The Chemical Abstracts Service (CAS) number for PC is 108-32-7. Propylene carbonate is listed in the Toxic Substances Control Act (TSCA) Inventory. Propylene carbonate is not classified in the Department of Transportation's (DOT's) hazard class system (Clark et al., n.d.). Table 6-1 summarizes regulatory information for PC.

Table 6-1. Regulatory Information for PC

Regulation	Applicability to PC
Clean Air Act	Not listed
Comprehensive Environmental Response, Compensation, and Liability Act	Not listed
Resource Conservation and Recovery Act	Not listed
Superfund Amendments and Reauthorization Act	Not listed
Clean Water Act	Not listed
Occupational Safety and Health Administration	Not listed
American Conference of Governmental and Industrial Hygienists	Not listed
International Agency for Research on Cancer	Not listed
National Institute for Occupational Safety and Health	Not listed
National Toxicology Program	Not listed

In addition, PC has a National Fire Protection Association (NFPA) health hazard rating of 1 (NFPA, n.d.). This rating includes materials that may cause irritation on exposure but only minor residual injury even if no treatment is given, including those that require use of an approved canister-type gas mask. Propylene carbonate has an NFPA flammability rating of 1. This rating includes materials that must be preheated before ignition can occur. These materials require significant preheating under all ambient temperature conditions before ignition and combustion occur. Propylene carbonate has an NFPA reactivity rating of 0, meaning that the solvent is normally stable even under fire exposure conditions and does not react with water.



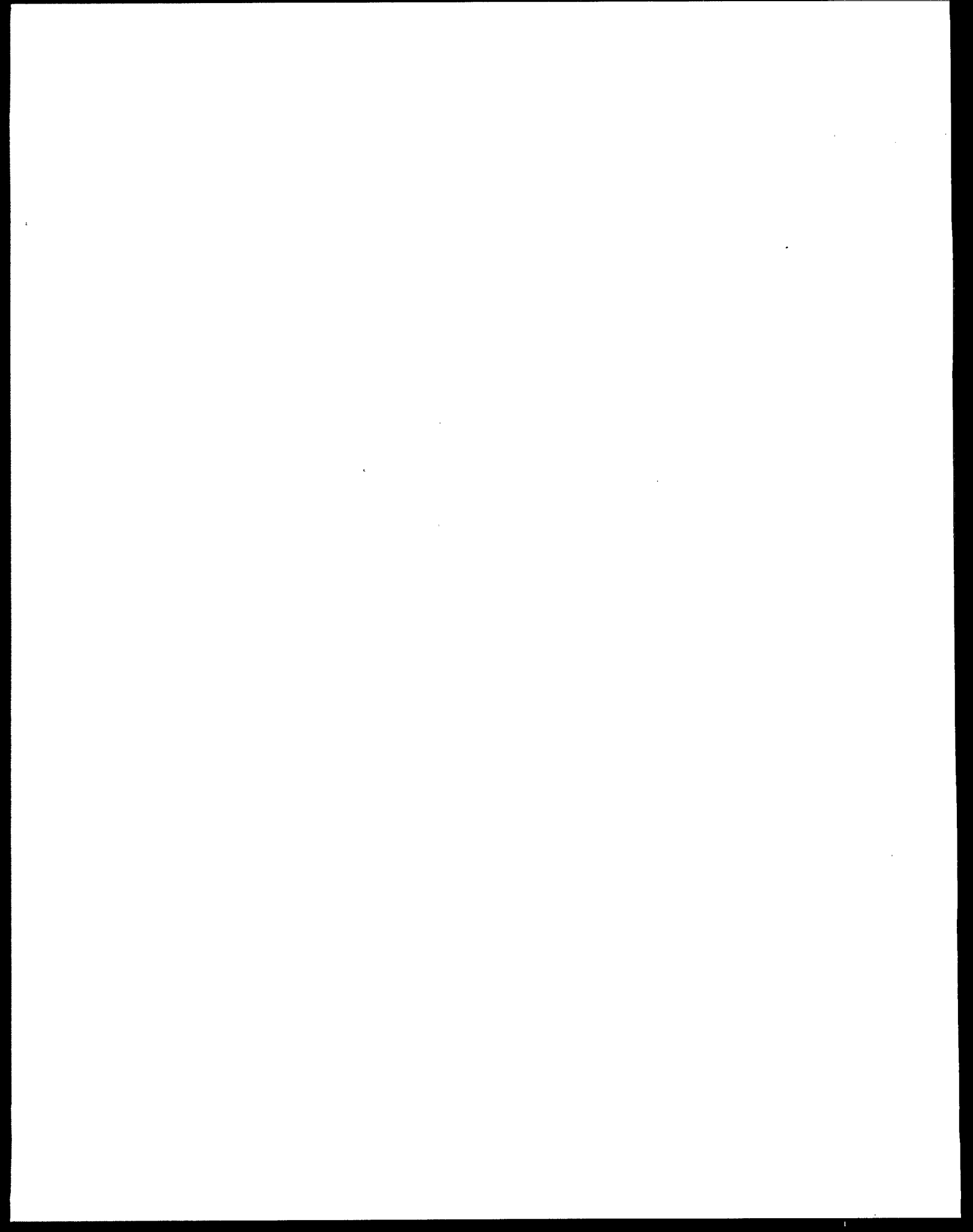
7.0 Summary

Propylene carbonate is an odorless, clear liquid that has a variety of commercial uses, including as an ingredient in cosmetics, as an extraction solvent, as an electrochemistry solvent, as a plasticizer, as an adhesive in food packaging, and in depainting. PC and various PC blends are under consideration as replacement solvents for MEK and methylene chloride in depainting operations. This report reviewed the available data regarding the performance of PC blends in depainting operations, their potential health hazards, and their potential environmental impacts.

Very little information on the environmental fate and transport of PC is available; however, based on its moderate water solubility and low vapor pressure, PC spilled onto soil could leach into ground water but would only be slowly released into the air. At least one study indicates that PC biodegrades fairly rapidly (up to 80 percent in 10 days) in domestic wastewater.

The available toxicity data indicate that PC is a mild skin and eye irritant with low acute, subchronic, and chronic toxicity. It is not known to be a reproductive toxin, a mutagen, or a carcinogen. Data compiled from hundreds of human volunteers exposed dermally to undiluted PC and various cosmetic formulations indicate that it is safe for cosmetic use. Worker exposures to PC during its manufacture or use are limited because of its low volatility and low skin permeation rate; however, repeated skin exposure can cause irritation.

The aquatic toxicity of PC is low. This finding, combined with an expected low persistence and bioaccumulation potential, indicate that environmental impacts of PC should be low.



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Appendix A

PROPYLENE CARBONATE CASE STUDIES

Depainting Case Studies

Pollution Prevention Demonstration and Evaluation of Paint Application Equipment and Alternatives to Methylene Chloride and Methyl Ethyl Ketone (J.M. Elion et al., EPA/600/SR-96/117, October 1996).

Introduction

This research provides results of a demonstration of PC as a possible alternative to MEK. The demonstration was conducted at the Marine Corps Logistics Base in Albany, GA. Activities involved the cleaning of paint application equipment with MEK. For this demonstration, a blend of 40 percent PC and 60 percent benzyl alcohol (BA), by weight, was chosen to replace MEK. This choice was based on the results of laboratory screening, materials compatibility, and paint removal efficiency tests. Based on the demonstration, PC/BA cleaned green CARCs from the pumps as well as MEK, and it cleaned epoxy primers better than MEK. If employed, this substitution would potentially reduce HAPs at the base by 21 percent from 1992 levels.

Results and Discussion

For this demonstration, a blend of PC/BA was chosen to replace MEK for cleaning paint application equipment such as pumps, hoses, and guns. Four 208-L barrels of this cleaner were used as a direct replacement for MEK. No capital investment was required.

Use of the PC/BA cleaner was monitored by weighing the amount of cleaner flushed through the system, including the amount used in the initial prewash, the final wash, and the filter wash. Results showed that the PC/BA cleaned green CARC from the pumps as well as MEK, and it cleaned epoxy primers from the pumps better than MEK based on the average gallons (volume) used and the time to clean the equipment. The use of the blend lowered worker exposure to hazardous material, reduced cleaner usage and labor time for cleaning, and significantly decreased the downtime of the primer pumps.

The advantages of using the PC/BA blend were its lower vapor pressure, its reduction in solvent use and labor time for cleaning, and its classification as a nonregulated hazardous waste by RCRA. The PC/BA blend effectively removed epoxy primers better than MEK, and substitution for MEK would potentially reduce HAPs at the Marine base by 21 percent from 1992 levels.

The disadvantage of the PC blend was that it cost more than MEK.

Although no capital investment was required, the cost of the PC/BA blend was higher than that of MEK, but the higher cost may be offset by cleaner recovery and reclamation and further waste reduction.

Substitutes for Methylene Chloride Paint Strippers--Performance Evaluation and Adaptation to Aircraft Maintenance Procedures. (G.E. Baker and E.F. Hollins, Pacific Environmental Services, Inc., Presented at the Air & Waste Management Association's 90th Annual Meeting & Exhibition, June 8-13, 1997, Toronto, Ontario, Canada).

Introduction

The recently promulgated National Emission Standards for Hazardous Air Pollutants (NESHAP) for the aircraft industry all but require the elimination of the use of methylene chloride-based paint strippers for the depainting of aircraft. Consequently, the pollution prevention division of the Oklahoma City Logistics Center at TAFB, an AFMC installation, must investigate possible ways to eliminate the use of methylene chloride-based strippers from its depainting operations. More than 80 percent of the depainting operations at TAFB involve KC-135 aircraft. The purpose of this research was to evaluate the performance of aircraft depainting solvents that may be used to replace the methylene chloride-based strippers. As part of the study, bench- and full-scale tests were conducted.

Results and Discussion

This research focused on identifying a drop-in replacement for the 19 percent phenolic-methylene chloride paint stripper currently used at TAFB. The replacement chosen must meet several criteria, including not being on the Toxic Release Inventory (TRI) list, being less hazardous to workers and to the environment, producing less waste, requiring less personal protective equipment for its use, costing less, and being usable in current spray delivery systems.

In bench-scale testing, 60 products from 30 vendors were identified that claimed to be alternatives to methylene chloride for paint stripping, including stripping of polyurethane aircraft primers. Of these 60 products, 15 were selected for extensive on-site testing. These products are listed in Table A-1.

Both analytical testing in the laboratory and on-site panel testing were conducted using tests prescribed in TAFB's LAPE 94-10A (purchase description testing regimen) testing method and several American Society for Testing and Materials (ASTM) tests, including ASTM D 92 (tests for flash point), D 2196 (tests for viscosity), and F 519 (tests for corrosion and hydrogen embrittlement). On-site test panels were 5- by 10-in aluminum alloy panels coated with a polysulfide primer and a polyurethane topcoat. Three different application, removal, and reapplication procedures were employed in these tests to examine the impacts of varying the coating thickness, varying the time of exposure of the panel to the solvent, and applying the

Table A-1. Listing of the Solvents Selected for Performance Evaluation

Vendor	Solvent name	Comments
Huntsman Chemical	7520-46-2T	PC blend
Huntsman Chemical	7520-46-5T	PC blend
Huntsman Chemical	7520-46-6T	PC blend
Huntsman Chemical	7520-46-1T	PC blend
Huntsman Chemical	7520-46-3T	PC blend
Huntsman Chemical	7520-46-4T	PC blend
Gage Chemical	Stingray 874	H ₂ O ₂ solvent
Gage Chemical	Stingray 880	Neutral in pH
Gage Chemical	Stingray 894	H ₂ O ₂ solvent
Turco Products	6813-E	Alkaline solvent
Turco Products	6840-S	Alkaline solvent
Turco Products	6867	A version of 6813
Eldorado	5000/3140	Two-part system, with H ₂ O ₂
Eldorado	5000/3170	Two-part system, with H ₂ O ₂
Eldorado	5000/1940	Current methylene chloride stripper used at TAFB

product according to the manufacturer's recommendations. All applications for the three procedures were conducted by pouring solvent on the panels.

None of the Huntsman blends passed the consistency or flow tests. Flash points for all but one of the blends were below 200 °F. Two of the Turco products failed the hydrogen embrittlement tests. All of the Gage and Eldorado products failed the flash point test.

Only the Huntsman blend 2 failed the corrosion tests on magnesium. Significant corrosion of the metal specimens occurred with all three Gage, both Eldorado, and two of the three Turco products, again predominantly where magnesium metal was present.

The results of the Eldorado and two Gage products were the complete removal of the topcoat and primer with only the first solvent application. Turco 6840-S also removed the paint but required a second application to achieve greater than 95 percent primer removal. The other two Turco products performed similarly, requiring a second application but left slightly more primer on the surface after the second application.

Project Summary Life Cycle Assessment for PC Blend 2 Aircraft Radome Depainter; R. Thomas and W.E. Franklin, EPA/600/SR-96/094, September 1996.

The purpose of this research effort was to conduct an LCA on a potential replacement solvent blend, PC2, for aircraft radome depainting at the Oklahoma City Air Logistics Center at TAFB. PC2 is comprised of 50/25/25 weight percent NMP, DBE, and PC. The study was designed to conduct the LCA with respect to energy requirements, solid wastes, atmospheric emissions, and waterborne wastes associated with and resulting from the production, use, and disposal of PC2 depainting solvent.

This case study provides the reader with information concerning an LCA conducted on a PC blend.

Project Summary Radome Depainting Evaluation at Tinker Air Force Base (EPA/600/SR-95/079, June 1995).

Introduction

This research describes a test program to determine the feasibility of using 10 possible alternative paint-stripping solvents, 5 of which were PC blends, that were less hazardous to the environment and public health than MEK. Testing involved immersing a 2- by 2-in square of an aircraft radome (a fiberglass and epoxy or polyester composite material, in a honeycomb structure) coated with a primer, a polyurethane rain-erosion coating, and a polyurethane antistatic topcoat, in a beaker of the selected solvent. Parameters evaluated included a visual assessment of the degree of attack (percent removal) on the coating in 0.5-, 1-, 2-, 4-, 8-, and 24-h increments.

Test results indicated that several of the solvents stripped the paint quicker and more efficiently than MEK. Although visual examination showed no damage to the substrate, there was some concern about potential substrate damage due to the complete and aggressive removal of all three coats. Three of the solvent PC blends completely removed the top two coats while leaving the primer untouched. Leaving the primer layer intact is considered a suitable alternative to complete paint removal. This process would ensure that the substrate is not damaged during the depainting operation. Additionally, it may provide some economic advantages in material and manpower savings.

Results and Discussion

The alternative solvents evaluated, along with their approximate compositions, are shown in Table A-2.

Table A-2. Alternative Solvents Evaluated

Alternative solvent:	Approximate composition of PC/NMP/DBE, %
Huntsman Formulation C #7210-60-1	40-60/10-30/15-35 percent PC/NMP/DBE
Huntsman Formulation D #7210-60-2	15-35/10-30/25-45 percent PC/NMP/DBE
Huntsman Formulation E #7210-60-3	15-35/40-60/ percent PC/DBE
Huntsman Formulation F #7210-60-4	35-55/30-50/ percent PC/DBE
Huntsman Formulation G #7210-60-5	30-50/30-50/ percent PC/DBE
Commercially available solvents:	
EZE Products, Inc. 540	Did not contain PC, NMP, or DBE
EZE Products, Inc. 542	Did not contain PC, NMP, or DBE
Turco Products, Inc. 6776 Lo	Did not contain PC, NMP, or DBE
Turco Products, Inc. 6776 Thin	Did not contain PC, NMP, or DBE
Turco Products, Inc. 6813	Did not contain PC, NMP, or DBE

The removal effectiveness of the solvents varied greatly. Some solvents, the EZE and Turco products, aggressively removed all three coats. The Huntsman formulations E, F, and G completely removed the first two coats while leaving the primer coat intact.

The purchase cost for each of the solvents evaluated is presented in Table A-3.

The costs for the commercially available strippers are as quoted, while those of the Huntsman formulations are calculated from the cost of the individual components multiplied by their percentage in the final blend; no cost of blending the mixtures was included, nor was a profit margin for the supplier of the blends.

Table A-3. Purchase Cost Comparison of Selected Solvents

Solvent/Blend	Approximate Cost, \$/gal
MEK	\$5.00
Huntsman Formulation F #7210-60-4	\$9.00
Huntsman Formulation E #7210-60-3	\$9.00
Huntsman Formulation G #7210-60-5	\$9.00
Huntsman Formulation D #7210-60-2	\$12.00
Huntsman Formulation C #7210-60-1	\$12.00
EZE Products, Inc. 540	\$14.00
Turco Products, Inc. 6776 Thin	\$17.00
Turco Products, Inc. 6813	\$17.00
Turco Products, Inc. 6776 Lo	\$17.00
EZE Products, Inc. 542	\$18.00

Project Summary Evaluation of Propylene Carbonate in Air Logistics Center (ALC) Depainting Operations. (S. Rosenthal, A.M. Hooper, Foster Wheeler Enviresponse, Inc., Edison, NJ. EPA/600/SR-94/176, September 1994).

Introduction

This report summarizes a two-phase, laboratory-scale screening study evaluating depainting solvent blends of PC as possible replacements for MEK in aircraft radome depainting operations. The first phase of screening evaluated the performance of solvent blends from Texaco Chemical Company containing varying percentages of PC, NMP, DBE, and other organic solvents. Performance was compared to that of MEK based on paint removal time and visual estimation of the amount of paint removed without any visible substrate damage. The best performing blend was PC2, containing 25/50/25 percent PC/NMP/DBE.

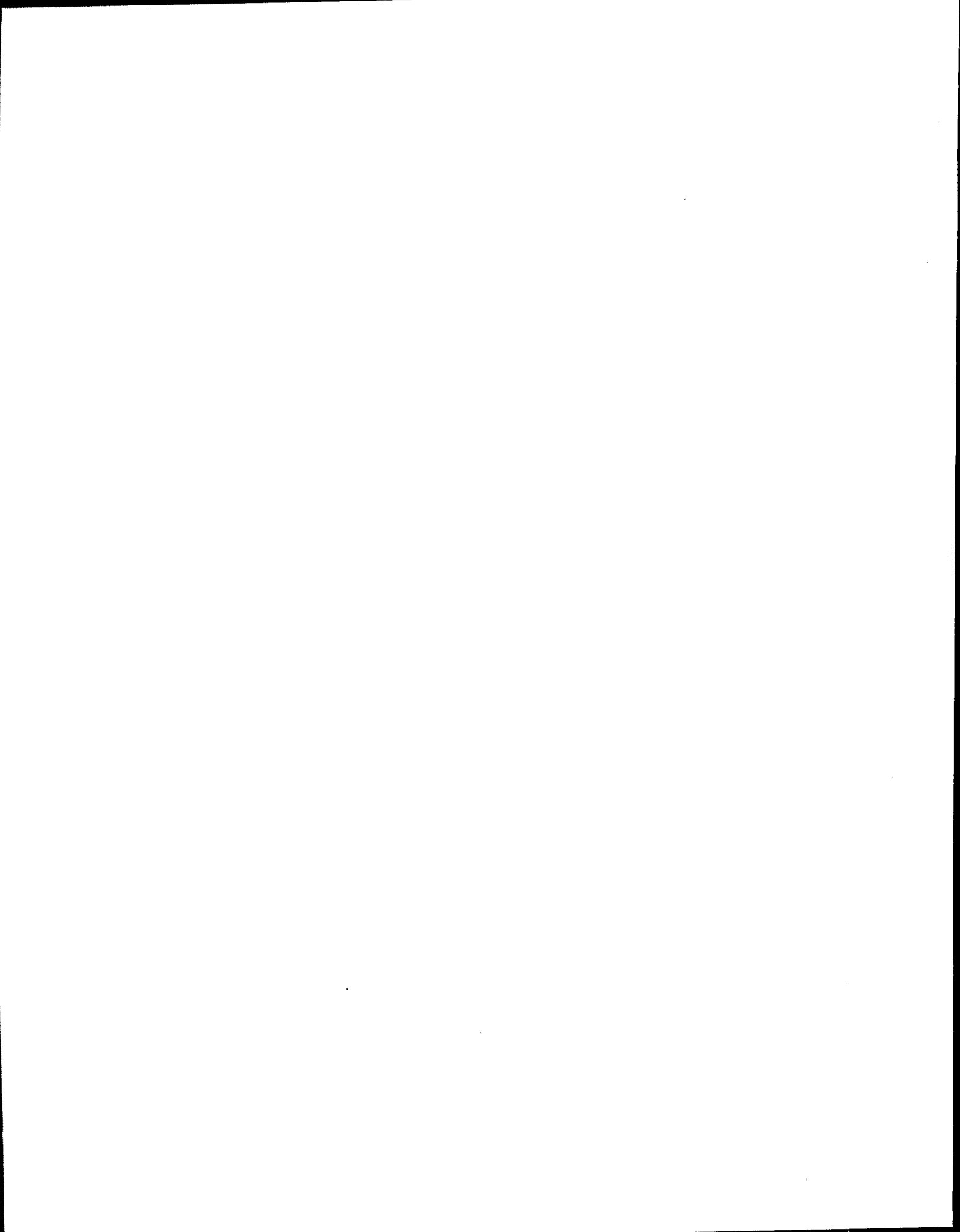
This solvent blend was then compared with MEK during the second phase of testing to measure paint removal time and efficiency, paint adhesion, flexural properties, weight change of the substrate after paint removal, and hardness of the unpainted substrate test panels. Results showed that PC2 performed favorably in comparison with MEK in removing paint from fiberglass and epoxy test panels and in subsequent paint adhesion tests, despite a possible indication of substrate damage.

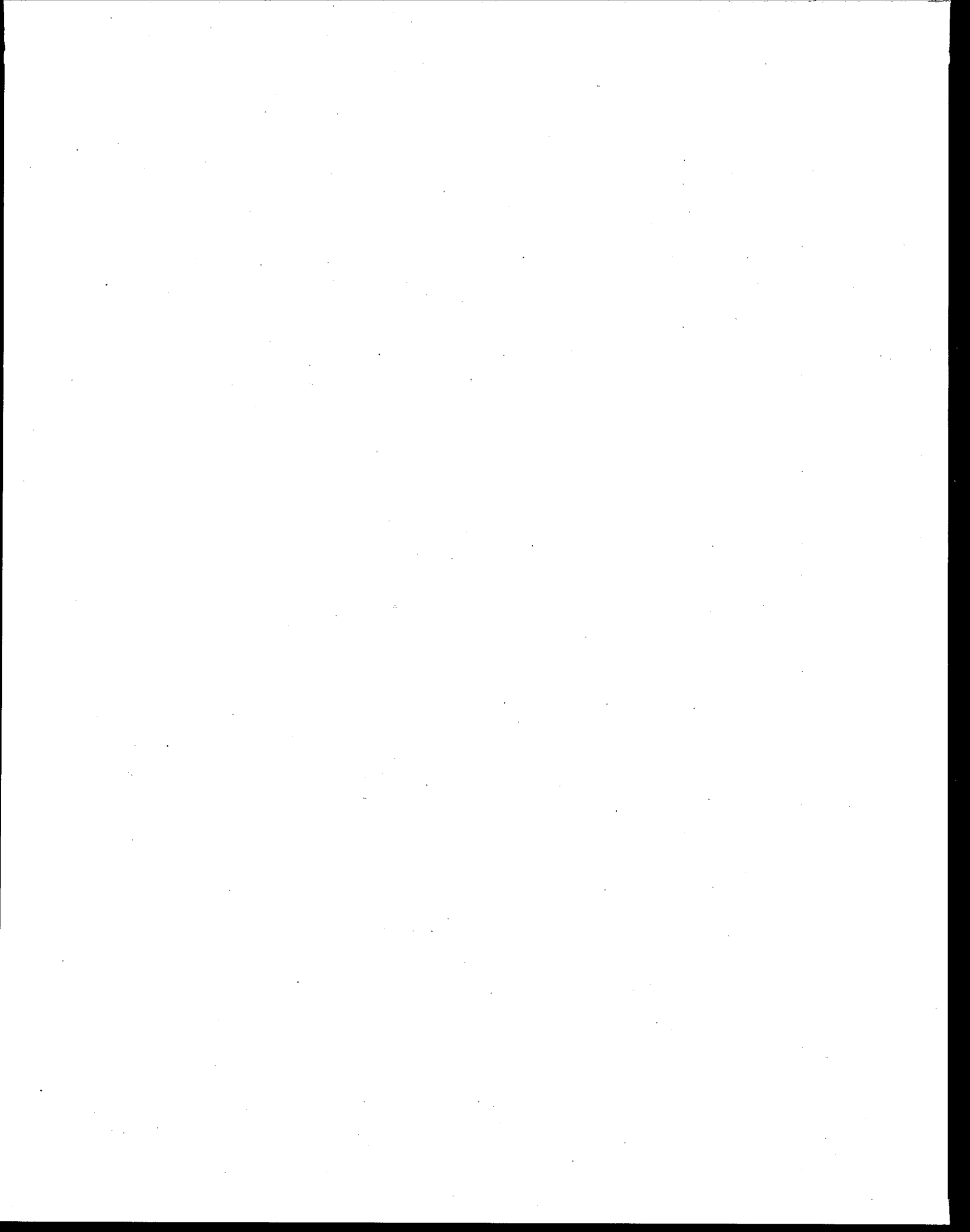
Results and Discussion

Results from the evaluation tests indicated that the best performing solvent blend was PC2. Compared to MEK, this solvent had the following results:

- PC2 removed 100 percent of the paint in about the same time as MEK and required more scraping for total removal.
- PC2 showed possible damage to the top resin layer of the fiberglass and epoxy substrate, which will require further study.
- PC2 and MEK panels exhibited a small weight loss after immersion for 4 h.
- PC2 and MEK did not impact paint adhesion.

Recommendations from the evaluation indicate that further examination of the potential adverse effects of the solvent on the substrate is necessary and that the issue of equipment compatibility, waste disposal practices, and procedures for removing the PC2 residue be further investigated.





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